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Thirty-day mortality after weekend versus weekday elective joint replacement in England and Wales: A Cohort Study Using the National Joint Registry Dataset

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Thirty-day mortality after weekend versus weekday elective joint replacement in England and Wales: A Cohort Study Using the National Joint Registry Dataset

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Abstract

Aims

To investigate whether elective joint replacement performed at the weekend is associated with a different 30-day mortality versus that performed between Monday and Friday.

Patients and Methods

We examined the 30-day cumulative mortality rate (Kaplan-Meier) for all elective hip and knee replacement procedures performed in England and Wales between 1st April 2003 and 31st December 2014, comprising 118,096 episodes done at the weekend and 1,233,882 episodes done on a weekday. We used Cox proportional-hazards regression models to assess for time-dependent variation and adjust for identified risk factors for mortality.

Results

The cumulative 30-day mortality for hip replacement was 0.15% (95%CI 0.12-0.19) for patients operated on at the weekend versus 0.20% (0.19-0.21) for patients undergoing surgery during the normal working week. For knee replacement, the cumulative 30-day mortality was 0.14% (0.11-0.17) for weekend-operated patients versus 0.18% (0.17-0.19) for weekday-operated patients. These differences were independent of any differences in patient age, gender, American Society of Anaesthesiologist grade, surgeon seniority, surgical and anaesthetic practices, and thromboprophylaxis choice in weekend versus weekday-operated patients.

Conclusion

The 30-day mortality rate after elective joint replacement is low. Surgery performed at the weekend is associated with lower post-operative mortality versus operations performed on a weekday.

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Introduction

Orthopaedic operating comprises approximately one-fifth of elective surgical activity in acute English hospitals during weekdays and one-quarter of elective activity at weekends.[1] Hip and knee replacement are some of the most commonly performed elective orthopaedic procedures, with approximately 170,000 undertaken annually in England and Wales in 2015.[2] With the increasing demand for hip and knee replacement,[3] and the increasing pressure to move towards routine seven-day services,[4,5] this weekend trend is set to increase.

Whilst acute admission episodes and emergency procedures performed at the weekend are associated with poorer outcomes and higher mortality than those occurring on weekdays,[6-8] the evidence around elective surgery is less clear. Mohammed et al examined patient discharges from all acute hospitals in England between April 2008 and March 2009 using Hospital Episode Statistics (HES) data.[1] They found that amongst 1,535,267 elective admissions weekend elective operating was associated with a 32% increase in 30-day mortality versus weekday operating compared with a 9% increase when considering only emergency surgery.[1] These effects remained after case-mix adjustment. Aylin et al also examined 30-day mortality after elective operations using HES data across 3 financial years, ending March 2011.[9] They included all planned, elective procedures in all acute and specialist hospitals in England, and stratified them into high-risk (for example, cardiac surgery) versus low-risk (joint replacement, hernias, veins, and tonsils). The overall adjusted odds of death were 44% higher for Friday operations and 82% higher for Saturday and Sunday operations versus those done on a Monday. However, in the low-risk procedures combined they found no difference in mortality risk following operations performed on a Saturday or Sunday versus those done on a Monday (odds ratio 0.92, $P>0.05$), and a slightly higher risk on Friday (odds of death 1.28, $P<0.05$) after adjustment for case-mix, deprivation index, and number of previous admissions.

Whether elective weekend hip and knee replacement associates with a differential mortality rate versus patients operated during weekdays remains an open question. However, if seven-day working is to succeed, then it is important to ensure that the most common elective procedures can be performed safely over the weekend. We analysed data from the National Joint Registry (www.njrcentre.org.uk) across England and Wales, and Office of National Statistics (www.ons.gov.uk) mortality data to

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determine if performing planned, elective total hip and total knee replacement on Saturdays and Sundays is associated with a different cumulative 30-day mortality versus those performed between Monday and Friday. We also examined whether any variations in mortality are associated with the healthcare sector in which the operation was performed, grade of operating surgeon, seasonal and temporal variation, and changes in patient fitness (assessed by ASA grade) or surgical practices over the 11-year period that the NJR has been recording data.

Patients and Methods

Sources of data

Our base data sets for analysis were the linkable 708,311 primary hip and 772,818 primary knee replacement procedures carried out in England and Wales between 1st April 2003 and the 31st December 2014.[10] Death data was ascertained from the Person Demographic Service of the Office for National Statistics via Northgate Public Services (www.northgateps.com) on 20th February 2015. We excluded 7,372 bilateral hip procedures (3,686 patients) and 18,122 bilateral knee procedures (9,061 patients) performed on the same day. Of the remainder, we included for analysis those 627,351 hips and 725,297 knees who had only osteoarthritis stated as the reason for surgery. A further 316 hips and 354 knees were excluded because the NHS numbers had not been traced or consent had been withdrawn, leaving 627,035 hips and 724,943 knees for analysis.

Statistical analyses

Kaplan-Meier estimates were used to describe the cumulative mortality up to 30-days and subgroups were compared with logrank tests. The effect of day of the week on 30-day mortality was further explored using Cox proportional-hazards regression models. Unadjusted hazard rate ratios (HRRs) were calculated to compare primaries undertaken at the weekend with those undertaken on a weekday (reference group). Temporal changes in the weekend effect were assessed by adding to the model their interactions with grouped year of primary (2003-5, 2006-8, 2009-11, or 2012-14).The Cox models were repeated with adjustment for the other covariates previously found to be related to short-term mortality within the NJR dataset,[11,12] namely gender, grouped age at surgery (<55, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84 or 85+ years), ASA grade (P1, P2, P3 to P5) and prosthesis type (cemented,

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uncemented, hybrid, reverse hybrid and resurfacing for hips and cemented, uncemented, hybrid, patellofemoral and unicondylar for knees), together with posterior surgical approach, mechanical and chemical thrombo-prophylaxis and anaesthetic type for hips.[11] Chi-squared tests were used to examine temporal and seasonal changes in the proportion of weekend cases plus temporal changes in gender and ASA at primary operation; differential temporal changes in the proportional of weekend cases amongst different ASA groups were explored with logistic regression models. A one-way analysis of variance (ANOVA) was used to test for temporal changes in mean age at operation. A 5% level of significance was used throughout.

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Results

Short term mortality by day of week of primary operation

54,091 hip replacements done at the weekend (Saturday 45,083 plus Sunday 9,008) were compared with the remaining 572,944; and 64,005 knee replacements done at the weekend (Saturday 52,544 plus Sunday 11,461) with the remaining 660,938 (Table 1). Overall, the cumulative mortality up to day 30 was lower for patients operated on at the weekend than for patients undergoing surgery during the normal working week across both the hip replacement and the knee replacement analysis strata ($P=0.011$ and $P=0.017$, respectively, by logrank test – Figure 1A and 1B).

Weekend working and mortality by hospital type

The overall pattern of weekend working was different between the NHS hospitals, the independent treatment centres and the independent hospitals, with independent hospitals having done the greatest percentage of their total number of operations at the weekend, and independent treatment centres the fewest (Table 2). The unadjusted 30-day mortality of patients undergoing joint replacement in NHS hospitals at the weekend was significantly lower than those operated on a week-day (Figures 2A and 2B; logrank test hips: $P=0.010$, knees: $P=0.002$), but not in the independent treatment centres and independent hospitals (hips: $P=0.32$ and $P=0.84$ respectively, and knees $P=0.97$ and $P=0.12$, respectively).

Factors associated with variations in mortality

Consultant effect

Virtually all of the operations in the independent treatment centre and independent hospitals were performed by a consultant, whilst 74% of the hip and 72% of the knee replacements done in NHS hospitals were performed by the consultant (Table 2). Amongst the NHS hospitals, the weekend hip replacement cases were more likely to have been performed by the consultant than were the weekday cases (28,547 (84%) of the 34,075 weekend cases were performed by the consultant compared with 287,062 (73%) of the 391,301 weekday cases). The same pattern was identified for knees (34,350 (81%) of the 42,315 weekend cases performed by consultant versus 331,304 (71%) of the 468,061 of the weekday cases). The weekend effect in the NHS hospitals was not explained by variation in operating surgeon seniority, as there was no difference in the cumulative mortality between those operated on by the consultant versus the remainder (Hips P=0.87 and Knees P=0.95 by logrank test, Figure 3). Adjustment for a consultant effect left the weekend effect unchanged (data not shown).

Seasonal effect

Division of the NHS hospital operations into those performed in Spring (March-May), Summer (June-August), Autumn (September-November) and Winter (December-February) demonstrated a slight, albeit statistically significant, seasonal variation in the proportions of cases performed at weekend (Table 3). For hip operations there was no difference in mortality between the seasons overall (Figure 4A, logrank test P=0.69). However, for knee operations 30-day mortality was highest in Spring (Figure 4B, logrank test P=0.017). The weekend effect for knee operations persisted when adjusted for season (Cox proportional-hazards: HRR 0.66 95%CI 0.51-0.85, P=0.002).

Temporal effects

Our previous work has highlighted the fall in early cumulative mortality over the period covered by the NJR.[11,12] There have also been changes in both the relative numbers of weekday operated versus weekend operated patients in NHS hospitals (Table 4), and their relative 30-day mortality across the time periods (2003 to 2005, 2006 to 2008, 2009 to 2011, and 2012 to 2014). In the early years the weekend operated patient mortality was similar to that of weekday operated patients. In the latter 2 time periods the weekend operated patients appeared to have a lower 30-day mortality than the weekday operated patients (Figure 5A, hips: 2003 to 2005 P=0.38, 2006 to 2008 P=0.39, 2009 to 2011

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P=0.07, 2012 to 2014 P=0.014; Figure 5B, knees: 2003 to 2005 P=0.84, 2006 to 2008 P=0.24, 2009 to 2011 P=0.007, 2012 to 2014 P=0.056).

For independent hospitals, we observed no significant differential mortality between weekend versus weekday-operated cases, with the exception of the period 2012 to 2014 in which the mortality for knees operated at the weekend appeared to have a higher mortality (logrank test P=0.039); 30-day Kaplan-Meier estimates for weekday and weekend operations in this latter period were 0.06% (95%CI 0.04% to 0.08%) and 0.13% (95%CI 0.07% to 0.23%) respectively, although numbers were small and there had only been 48 30-day deaths. We did not repeat this for independent sector treatment centres as numbers were smaller.

What is accounting for the changing mortality patterns in NHS hospitals?

The proportion of patients of ASA grades P2 and P3 to P5 being operated in NHS hospitals has increased between 2003 and 2014~~, whilst the average age at surgery and gender distribution has remained largely unchanged~~ (Table 5). Although the overall proportion of weekend cases had increased from 2006 onwards, the increases were apparent amongst the ASA groups P1 and P2 only (Table 6). These differences were confirmed using logistic regression models to examine the factors related to the proportion of 'weekend' cases, with grouped year of primary operation and ASA P1 vs P2 vs P3 to P5 used as predictors. Significant interactions between grouped year and ASA (P<0.001), in both hips and knees, confirmed different temporal effects for the ASA groups identified in Table 6.

Although there were statistically significant changes between the four time periods in respect of gender and mean age (Table 5), the effects were small. Slightly fewer men were operated on at the weekend than women (Chi-squared test; Hips: 7.7% of 172,478 men versus 8.2% of 252,894 women, P<0.001; Knees 8.2% of 218,216 men versus 8.4% of 292,154 women, P=0.018) and these gender differences did not vary significantly between the year groups (interaction P=0.15 for hips and P=0.36 for knees). Patients operated at the weekend were slightly younger than those operated during weekdays, but the differences were very small (hips: mean age difference 0.17 years (95%CI 0.06 to 0.29), knees: 0.11 years (95%CI 0.02 to 0.21)). Linear regression analysis (not shown) showed that the age differences between weekday and weekend cases varied between the year groups (Hips: P<0.001; knees P=0.023), with a trend of weekend cases becoming younger than weekday cases for hips although these differences were also very small (data not shown).

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Impact of known mortality risk factors

Cox proportional-hazards models were used to further explore the changing weekend mortality effects to see if the pattern persists after accounting for the observed changes in the known mortality risk factors. Without adjusting for other factors, there was a significant interactive effect on mortality between 'weekend' and year group of surgery ($P<0.001$ for both hips and knees, likelihood-ratio test), confirming that the weekend effect varied between the 4 time periods. The interaction between weekend effect and grouped year of surgery became non-significant, however, with further adjustment for grouped age at surgery, gender and ASA grade (test for interaction $P=0.20$ and $P=0.25$, for hips and knees respectively).

Models (1) in Table 7 show adjusted HRRs for weekend working for hips and knees overall, assuming these effects were constant across the 4 time periods and dropping the interaction terms. The HRRs were 0.79 (95%CI 0.61 to 1.03; $P=0.086$) and 0.72 (95%CI 0.55 to 0.93; $P=0.012$), respectively, for hips and knees, adjusting for age, gender, ASA and year of primary.

Between 2003 to 2014 there has been a temporal change in anaesthetic practises in favour of spinal techniques, and increased use of chemical and mechanical thrombo-prophylaxis.[11,12] For hips, adjustment for changes in modifiable variables that influence mortality, namely use of the posterior approach, mechanical and chemical thrombo-prophylaxis, anaesthetic technique, and prosthesis type (cemented, uncemented, hybrid, reverse hybrid and resurfacing), confirmed no significant interaction between weekend and grouped year of surgery ($P=0.15$; based on 413,809 surgical episodes with complete information). Similarly, for knees further adjustment for the prosthesis type (cemented, uncemented, hybrid, patellofemoral or unicondylar), as well as seasonality, confirmed no interaction between weekend and year of surgery ($P=0.25$; based on 510,336 surgical episodes with complete information). The hip and knee models (2) in Table 7 show the respective overall HRRs for weekend working adjusting for the additional risk factor variables; the adjusted HRRs were 0.82 (95%CI 0.63-1.07; $P=0.14$) and 0.70 (95%CI 0.54-0.91; $P=0.008$) for hips and knees.

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Discussion

We used the NJR dataset to ask whether patients undergoing hip or knee replacement across England and Wales at the weekend have a different 30-day mortality rate versus those operated on a weekday. We found that the 30-day mortality after joint replacement in England and Wales was very low overall, and was lower for weekend-operated patients in NHS hospitals, but not in the independent sector. Amongst NHS hospitals, the weekend effect was consistent across both hip and knee replacement operations, but appeared stronger in more recent years. We have previously reported 45 and 90-day mortality rates for knees and hips, respectively,[11,12] When the weekend effect analysis is repeated using these timeframes and with full adjustment for all relevant covariates the outcome of the weekend effect analysis remained unchanged.

Our findings contrast with those of Mohammed et al, who found increased mortality in weekend-operated elective cases in England.[1,13] One possible explanation for these discrepant findings is that the in the Mohammed study patient mortality rates were not stratified by Health Related Group (HRG) chapter. Other factors, such as weekend nurse staffing and education levels that may affect mortality rates are not recorded in the NJR,[14] and it is possible that the lower weekend-operated mortality might occur despite a lower quality of care. It is also logical to assume that younger and fitter patients are selected for weekend surgery when staffing levels are lower. However, when these factors are adjusted for in the analyses, the weekday-weekend differential mortality remains. Our findings also contrast with studies of emergency and high risk elective surgery that are associated with higher mortality when operated on Saturday or Sunday.[6,8,13,15] Patients undergoing hip and knee replacement in the UK do not differ markedly from those undergoing these same operations in other European countries, North America or Australasia and operative techniques are comparable.[16] Our results are thus likely to be generalisable to health economies with similar clinical practices.

We, and others, have reported a temporal decline in overall post-operative mortality rates over the last 10 years, despite an overall increase in patient co-morbidities.[11,12,17-20] This lower mortality may relate, in part, to changes in anaesthetic practice. Perlas et al,[21] in a propensity score matched cohort study of patients after hip or knee replacement found a 30-day mortality rate of 0.19% in patients who had

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undergone spinal anaesthetic versus 0.8% patients who had undergone a general anaesthetic (risk ratio, 0.42; 95% CI, 0.21 to 0.83; P = 0.0045). However, this general decline in mortality does not explain the difference found between weekend versus weekday operations. Such differences may be accounted for by factors not recorded in the NJR dataset. For example, whilst the NJR records data on operating surgeon seniority, and anaesthetic technique, it does not record information on the experience of the anaesthetist, nor comorbidities beyond the ASA classification. Anaesthetist experience may be of relevance,[22] as in some high-risk surgical populations, anaesthetic procedure-specific experience associates with lower perioperative mortality.[23,24] However, it is unclear whether such influences extend to lower-risk procedures such as elective joint replacement.

We used the ASA grade as a measure of comorbidity. The Charlson comorbidity index is a widely used alternate approach,[25] and the 2 indices are correlated.[26-28] Both showed similar predictive power in identifying patients at increased 90-day mortality risk after hip replacement in a national cohort of 24,699 patients from Sweden (ASA grade 3 or more 90-day mortality adjusted HR 9.5 (95%CI 3.5 to 25.8); Charlson Comorbidity Index HR8.4 (7.5 to 9.4).[29] We did not include BMI in the main analysis because the NJR data is incomplete in this area. We have previously shown that underweight patients have a higher 45 and 90-day mortality risk than patients with a BMI in the 19 to 25kg/m^2 range, and that overweight (BMI 26 to 30kg/m^2) and obese patients (BMI >30kg/m^2) have a lower mortality.[11,12,19] Further adjustment of the current analyses for BMI group based on 206,060 hip and 251,718 knee replacement episodes confirmed lower mortality in the weekend cases for both hips and knees, and was not affected by BMI. The hazard rate ratios for the weekend cases, adjusting for age, gender, ASA, year of surgery, BMI subgroup and all the other operative factors mentioned (plus 'season' for knees), were 0.59 (0.36 to 0.98), P=0.041 for hips; and 0.64 (0.43-0.97), P=0.036 for knees.

In conclusion, our findings indicate that planned, weekend joint replacement surgery is safe under existing working practises. Our analysis used a disease and procedure-specific national clinical audit to maximise capture of activity over an 11-year period, minimise sampling bias, and adjust for known variations in clinical settings, practises and procedures. Modelling strategies that examine the interactions between clinical decision-making, service provision, patient risk profiles, and procedure volume and complexity are required to fully understand the weekend effect.

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Take home message

Hip and knee replacement is routinely performed on Saturdays, and to a lesser extent on Sundays, in England and Wales and it is not associated with an increased risk of post-operative mortality.

References

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1. Mohammed MA, Sidhu KS, Rudge G, Stevens AJ. Weekend admission to hospital has a higher risk of death in the elective setting than in the emergency setting: a retrospective database study of national health service hospitals in England. *BMC Health Serv Res 2012;12:87.*

2. National Joint Registry for England, Wales, Northern Ireland and the Isle of Man 13th Annual Report. www.njrcentre.org.uk, 2016.

3. Patel A, Pavlou G, Mujica-Mota RE, Toms AD. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with projections for the United States. A study using the National Joint Registry dataset. *Bone Joint J 2015;97-B-8:1076-81.*

4. NHS England: NHS Services, Seven Days a Week Forum: Summary of Initial Findings. https://www.england.nhs.uk/wp-content/uploads/2013/12/forum-summary-report.pdf, December, 2013.

5. NHS England: Five year forward view. www.england.nhs.uk/wp-content/uploads/2014/10/5yfv-web.pdf, October 2014.

6. Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. *N Engl J Med 2001;345-9:663-8.*

7. Freemantle N, Richardson M, Wood J, Ray D, Khosla S, Shahian D, Roche WR, Stephens I, Keogh B, Pagano D. Weekend hospitalization and additional risk of death: an analysis of inpatient data. *J R Soc Med 2012;105-2:74-84.*

8. McCallum IJ, McLean RC, Dixon S, O'Loughlin P. Retrospective analysis of 30-day mortality for emergency general surgery admissions evaluating the weekend effect. *Br J Surg 2016;103-11:1557-65.*

9. Aylin P, Alexandrescu R, Jen MH, Mayer EK, Bottle A. Day of week of procedure and 30 day mortality for elective surgery: retrospective analysis of hospital episode statistics. *BMJ 2013;346:f2424.*

10. National Joint Registry 12th Annual Report. www.njrreports.org.uk, 2015.

11. Anonymised for review. 90-day mortality after 409,096 total hip replacements for osteoarthritis, from the National Joint Registry for England and Wales: a retrospective analysis. *Lancet 2013;382-9898:1097-104.*

12. Anonymised for review. 45-day mortality after 467 779 knee replacements for osteoarthritis from the National Joint Registry for England and Wales: an observational study. *Lancet 2014.*

13. McIsaac DI, Bryson GL, van Walraven C. Elective, major noncardiac surgery on the weekend: a population-based cohort study of 30-day mortality. *Med Care 2014;52-6:557-64.*

14. Aiken LH, Sloane DM, Bruyneel L, Van den Heede K, Griffiths P, Busse R, Diomidous M, Kinnunen J, Kozka M, Lesaffre E, McHugh MD, Moreno-Casbas MT, Rafferty AM, Schwendimann R, Scott PA, Tishelman C, van Achterberg T, Sermeus W,

consortium RC. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *Lancet 2014;383-9931:1824-30.*

15. Freemantle N, Ray D, McNulty D, Rosser D, Bennett S, Keogh BE, Pagano D. Increased mortality associated with weekend hospital admission: a case for expanded seven day services? *BMJ 2015;351:h4596.*

16. Ackerman IN, Bohensky MA, de Steiger R, Brand CA, Eskelinen A, Fenstad AM, Furnes O, Garellick G, Graves SE, Haapakoski J, Havelin LI, Makela K, Mehnert F, Pedersen AB, Robertsson O. Substantial rise in the lifetime risk of primary total knee replacement surgery for osteoarthritis from 2003 to 2013: an international, population-level analysis. *Osteoarthritis Cartilage 2016.*

17. Cram P, Lu X, Kaboli PJ, Vaughan-Sarrazin MS, Cai X, Wolf BR, Li Y. Clinical characteristics and outcomes of Medicare patients undergoing total hip arthroplasty, 1991-2008. *JAMA 2011;305-15:1560-7.*

18. Kirksey M, Chiu YL, Ma Y, Della Valle AG, Poultsides L, Gerner P, Memtsoudis SG. Trends in in-hospital major morbidity and mortality after total joint arthroplasty: United States 1998-2008. *Anesth Analg 2012;115-2:321-7.*

19. Anonymised for review. Mortality after total hip replacement surgery: A systematic review. *Bone Joint Res 2014;3-6:175-82.*

20. Parvizi J, Johnson BG, Rowland C, Ereth MH, Lewallen DG. Thirty-day mortality after elective total hip arthroplasty. *Journal of Bone and Joint Surgery 2001;83-A-10:1524-8.*

21. Perlas A, Chan VW, Beattie S. Anesthesia Technique and Mortality after Total Hip or Knee Arthroplasty: A Retrospective, Propensity Score-matched Cohort Study. *Anesthesiology 2016;125-4:724-31.*

22. Aldridge C, Bion J, Boyal A, Chen YF, Clancy M, Evans T, Girling A, Lord J, Mannion R, Rees P, Roseveare C, Rudge G, Sun J, Tarrant C, Temple M, Watson S, Lilford R, Hi SC. Weekend specialist intensity and admission mortality in acute hospital trusts in England: a cross-sectional study. *Lancet 2016;388-10040:178-86.*

23. Hofer I, Spivack J, Yaport M, Zerillo J, Reich DL, Wax D, DeMaria S, Jr. Association between anesthesiologist experience and mortality after orthotopic liver transplantation. *Liver Transpl 2015;21-1:89-95.*

24. Zgleszewski SE, Graham DA, Hickey PR, Brustowicz RM, Odegard KC, Koka R, Seefelder C, Navedo AT, Randolph AG. Anesthesiologist- and System-Related Risk Factors for Risk-Adjusted Pediatric Anesthesia-Related Cardiac Arrest. *Anesth Analg 2016;122-2:482-9.*

25. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis 1987;40-5:373-83.*

26. Lavelle EA, Cheney R, Lavelle WF. Mortality Prediction in a Vertebral Compression Fracture Population: the ASA Physical Status Score versus the Charlson Comorbidity Index. *Int J Spine Surg 2015;9:63.*

27. Guo R, Yu W, Meng Y, Zhang K, Xu B, Xiao Y, Wu S, Pan B. Correlation of ASA Grade and the Charlson Comorbidity Index With Complications in Patients After Transurethral Resection of Prostate. *Urology 2016;98:120-5.*

28. Whitmore RG, Stephen JH, Vernick C, Campbell PG, Yadla S, Ghobrial GM, Maltenfort MG, Ratliff JK. ASA grade and Charlson Comorbidity Index of spinal surgery patients: correlation with complications and societal costs. *Spine J 2014;14-1:31-8.*

29. Hailer NP, Garland A, Rogmark C, Garellick G, Karrholm J. Early mortality and morbidity after total hip arthroplasty in patients with femoral neck fracture. *Acta Orthop 2016;87-6:560-6.*

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Table 1. Cumulative mortality at 7 and 30 days after primary hip and knee replacement, shown separately according to whether or not the primary operation was performed at the weekend.

Hip Replacement					
Primary operation	Number of cases	At 7 days		At 30 days	
		Deaths	Cumulative mortality (Kaplan-Meier, with 95% CIs)	Deaths	Cumulative mortality (Kaplan-Meier, with 95% CIs)
Weekdays	572,944	486	0.08% (0.08%-0.09%)	1,146	0.20% (0.19%-0.21%)
Weekend	54,091	31	0.06% (0.04%-0.08%)	81	0.15% (0.12%-0.19%)
Total	*627,035*	*517*	*0.08% (0.08%-0.09%)*	*1,227*	*0.20% (0.19%-0.21%)*
Knee Replacement					
Primary operation	Number of cases	At 7 days		At 30 days	
		Deaths	Cumulative mortality (Kaplan-Meier, with 95% CIs)	Deaths	Cumulative mortality (Kaplan-Meier, with 95% CIs)
Weekdays	660,938	521	0.08% (0.07%-0.09%)	1,183	0.18% (0.17%-0.19%)
Weekend	64,005	37	0.06% (0.04%-0.08%)	88	0.14% (0.11%-0.17%)
Total	*724,943*	*558*	*0.08% (0.07%-0.08%)*	*1,271*	*0.18% (0.17%-0.19%)*

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Table 2. Number of patients undergoing primary hip or knee replacement stratified by type of hospital showing proportions of weekend operations and those performed by the consultant surgeon.

Hip Replacement			
Type of unit	Number of operations	Number (%) of operations performed at the weekend	Number (%) of operations performed by the consultant
NHS hospital	425,376	34,075 (8.0%)	315,609 (74.2%)
Independent treatment centre	26,828	1,048 (3.9%)	26,294 (98.0%)
Independent hospital	174,831	18,968 (10.9%)	173,926 (99.5%)
Total	*627,035*	*54,091 (8.6%)*	*515,829 (82.3%)*
Comparison between 3 types of unit (chi-squared test)		*P<0.001*	*P<0.001*
Knee Replacement			
Type of unit	Number of operations	Number (%) of operations performed at the weekend	Number (%) of operations performed by the consultant
NHS hospital	510,376	42,315 (8.3%)	365,654 (71.6%)
Independent treatment centre	34,057	1,260 (3.7%)	33,405 (98.1%)
Independent hospital	180,510	20,430 (11.3%)	179,329 (99.4%)
Total	*724,943*	*64,005 (8.8%)*	*578,388 (79.8%)*
Comparison between 3 types of unit (chi-squared test)		*P<0.001*	*P<0.001*

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Table 3 Operations performed by season in NHS Hospitals

Hip replacement		
Season of primary operation	Number of operations	Number (%) operations performed at the weekend
Spring	104,988	9,022 (8.6%)
Summer	107,867	7,971 (7.4%)
Autumn	115,463	9,110 (7.9%)
Winter	97,058	7,972 (8.2%)
Total	*425,376*	*34,075 (8.0%)*
Comparison between 4 seasons (chi-squared test)		*P<0.001*
Knee Replacement		
Season of primary operation	Number of operations	Number (%) operations performed at the weekend
Spring	125,035	11,138 (8.9%)
Summer	128,458	9,796 (7.6%)
Autumn	140,699	11,601 (8.3%)
Winter	116,184	9,780 (8.4%)
Total	*510,376*	*42,315 (8.3%)*
Comparison between 4 seasons (chi-squared test)		*P<0.001*

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Table 4. Number (and percentage by total number) of hip and knee operations that were performed at the weekend by hospital type

Hip Replacement			
Year of primary operation	Type of unit		
	NHS hospital	Independent treatment centre	Independent hospital
2003-5	2,969/48,222 (6.2%)	128/902 (14.2%)	2,807/24,298 (11.6%)
2006-8	8,732/108,681 (8.0%)	291/8,796 (3.3%)	3,770/37,844 (10.0%)
2009-11	10,068/128,902 (7.8%)	248/9,146 (2.7%)	5,431/49,957 (10.9%)
2012-14	12,306/139,571 (8.8%)	381/7,984 (4.8%)	6,960/62,732 (11.1%)
All years	*34,075/425,376 (8.0%)*	*1,048/26,828 (3.9%)*	*18,968/174,831 (10.9%)*
Comparison between 4 time periods (chi-squared test)	*P<0.001*	*P<0.001*	*P<0.001*
Knee Replacement			
Year of primary operation	Type of unit		
	NHS hospital	Independent treatment centre	Independent hospital
2003-5	3,491/53,130 (6.6%)	201/1,155 (17.4%)	2,514/21,765 (11.6%)
2006-8	10,971/129,799 (8.5%)	301/11,114 (2.7%)	3,878/35,703 (10.9%)
2009-11	12,924/158,262 (8.2%)	310/11,873 (2.6%)	6,053/52,975 (11.4%)
2012-14	14,929/169,185 (8.8%)	448/9,915 (4.5%)	7,985/70,067 (11.4%)
All years	*42,315/510,376 (8.3%)*	*1,260/34,057 (3.7%)*	*20,430/180,510 (11.3%)*
Comparison between 4 time periods (chi-squared test)	*P<0.001*	*P<0.001*	*P=0.022*

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Table 5. Temporal changes in ASA grade, gender and age distribution in patients undergoing surgery in NHS hospitals

Hip Replacement						
Year of primary operation	Total	ASA			% Males	Mean (SD) Age in years at primary
		P1	P2	P3+P4+P5		
2003-5	48,222	25.4%	59.9%	14.7%	40.9%	68.5 (10.4)
2006-8	108,681	17.1%	67.1%	15.8%	40.5%	68.5 (10.7)
2009-11	128,902	13.2%	69.6%	17.1%	40.8%	68.8 (10.8)
2012-14	139,571	11.3%	69.3%	19.4%	40.3%	69.1 (10.7)
All years	*425,376*	*15.0%*	*67.8%*	*17.2%*	*40.5%*	*68.8 (10.7)*
Comparison between 4 time periods		*P<0.001 (chi-squared test)*			*P=0.018 (chi-squared test)*	*P<0.001 (one-way ANOVA)*
Knee Replacement						
Year of primary operation	Total	ASA			% Males	Mean (SD) Age in years at primary
		P1	P2	P3+P4+P5		
2003-5	53,130	20.7%	63.2%	16.1%	43.6%	70.3 (9.0)
2006-8	129,799	12.8%	70.6%	16.6%	42.5%	69.6 (9.3)
2009-11	158,262	9.7%	72.3%	18.1%	43.0%	69.3 (9.6)
2012-14	169,185	8.1%	72.5%	19.4%	42.5%	69.2 (9.6)
All years	*510,376*	*11.1%*	*71.0%*	*17.9%*	*42.8%*	*69.4 (9.5)*
Comparison between 4 time periods		*P<0.001 (chi-squared test)*			*P<0.001 (chi-squared test)*	*P<0.001 (one-way ANOVA)*

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Table 6. Temporal change in the percentage of all hip and knee operations done at the weekend in NHS hospitals across the years of the registry, subdivided by ASA group

Hip Replacement								
ASA	Year of the primary							
	2003-5		2006-8		2009-11		2012-14	
	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)
P1	12,270	5.6 (5.2-6.0)	18,580	7.7 (7.3-8.1)	17,066	8.3 (7.9-8.7)	15,829	10.3 (9.8-10.7)
P2	28,871	6.5 (6.3-6.8)	72,947	8.3 (8.1-8.5)	89,751	8.2 (8.0-8.4)	96,731	9.3 (9.1-9.5)
P3-P5	7,081	5.6 (5.1-6.2)	17,154	7.1 (6.8-7.5)	22,085	5.9 (5.6-6.2)	27,011	6.2 (5.9-6.5)
Knee replacement								
ASA	Year of the primary							
	2003-5		2006-8		2009-11		2012-14	
	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)	N	% done as a weekend case (95%CI)
P1	11,010	6.4 (5.9-6.8)	16,649	7.9 (7.5-8.3)	15,298	8.8 (8.4-9.3)	13,741	9.1 (8.7-9.6)
P2	33,590	6.7 (6.5-7.0)	91,644	8.8 (8.6-9.0)	114,366	8.4 (8.3-8.6)	122,664	9.3 (9.1-9.4)
P3-P5	8,530	6.3 (5.8-6.8)	21,507	7.5 (7.2-7.9)	28,598	6.7 (6.4-7.0)	32,780	6.9 (6.6-7.2)

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Table 7 Cox 'proportional hazards' regression models to look at the effect of weekend working on hip and knee mortality up to 30 days from primary in NHS hospitals with adjustment for other factors.

Hip replacement				
Risk factors		**n**	**Model (1)** *425,372 cases with complete information; 999 30-day deaths* *With adjustment also for (grouped) age at primary and gender** **HRR (95%CI), P-value**	**Model (2)** *413,809 cases with complete information; 963 30-day deaths* *With adjustment also for (grouped) age at primary and gender** **HRR (95%CI), P-value**
Weekend working	**Weekday**	391,301	1 [referent]	1 [referent]
	Weekend	34,075	0.79 (0.61-1.03) P=0.086	0.82 (0.63-1.07) P=0.14
Year of primary	**2003-5**	48,222	1 [referent]	1 [referent]
	2006-8	108,681	0.79 (0.66-0.96) P=0.017	0.85 (0.70-1.04) P=0.11
	2009-11	128,902	0.57 (0.47-0.69) P<0.001	0.64 (0.52-0.79) P<0.001
	2012-14	139,571	0.41 (0.34-0.50) P<0.001	0.48 (0.38-0.60) P<0.001
ASA	**P1**	63,745	1 [referent]	1 [referent]
	P2	288,300	1.38 (1.05-1.81) P=0.022	1.50 (1.12-2.02) P=0.007
	P3-P5	73,331	3.01 (2.27-3.99) P<0.001	3.34 (2.47-4.51) P<0.001
Surgical approach	**Other**	203,186		1 [referent]
	Posterior	222,190		0.91 (0.79-1.03) P=0.14
Mechanical prophylaxis *(missing 844 or 0.2%)*	**None**	53,657		1 [referent]
	Any	370,875		0.85 (0.70-1.02) P=0.078
Chemical prophylaxis *(missing 844 or 0.2%)*	**None**	32,767		1 [referent]
	Aspirin only	39,403		0.75 (0.57-1.00) P=0.047
	Heparin +/- aspirin	283,601		0.72 (0.58-0.89) P=0.003
	Others/ Other combs.	68,761		0.81 (0.62-1.06) P=0.13
Anaesthetic *(missing 10,802 or 2.5%)*	**Spinal only**	191,994		1 [referent]
	GA only	97,013		1.11 (0.94-1.30) P=0.22
	Epidural only	16,023		1.14 (0.83-1.56) P=0.41
	Nerve block only	2,947		1.96 (1.15-3.34) P=0.013
	Spinal+GA	47,275		0.92 (0.73-1.16) P=0.49

	Spinal+epidural	5,993		0.88 (0.54-1.44) P=0.62
	Spinal+nerve block	10,414		0.75 (0.47-1.20) P=0.23
	GA+epidural	11,927		1.08 (0.76-1.55) P=0.65
	GA+nerve block	27,850		1.12 (0.87-1.44) P=0.39
	Other combinations	3,138		1.43 (0.79-2.61) P=0.24
Hip type *(missing 22 or 0.01%)*	**Cemented**	163,371		1 [referent]
	Uncemented	159,963		0.93 (0.80-1.09) P=0.40
	Hybrid	72,154		0.93 (0.77-1.11) P=0.41
	Reverse hybrid	9,817		1.05 (0.70-1.56) P=0.82
	Resurfacing	20,049		0.70 (0.37-1.34) P=0.28
Knee replacement				
		n	**Model (1)** ***510,369 cases with complete information; 1,065 30-day deaths*** ***With adjustment also for (grouped) age at primary and gender**** **HRR (95%CI), P-value**	**Model (2)** ***510,336 cases with complete information; 1,065 30-day deaths*** ***With adjustment also for (grouped) age at primary and gender**** **HRR (95%CI), P-value**
Weekend working	**Weekday**	468,061	1 [referent]	1 [referent]
	Weekend	42,315	0.72 (0.55-0.93) P=0.012	0.70 (0.54-0.91) P=0.008
Year of primary	**2003-5**	53,130	1 [referent]	1 [referent]
	2006-8	129,799	0.89 (0.74-1.08) P=0.23	0.89 (0.73-1.07) P=0.21
	2009-11	158,262	0.66 (0.55-0.80) P<0.001	0.66 (0.54-0.80) P<0.001
	2012-14	169,185	0.47 (0.38-0.57) P<0.001	0.46 (0.38-0.57) P<0.001
ASA	**P1**	56,697	1 [referent]	1 [referent]
	P2	362,264	1.48 (1.12-1.97) P=0.006	1.46 (1.10-1.93) P=0.009
	P3-P5	91,415	2.75 (2.06-3.68) P<0.001	2.68 (2.01-3.59) P<0.001
Knee type *(missing 33 or 0.01%)*	**Cemented**	438,231		1 [referent]
	Uncemented	23,855		1.11 (0.85-1.45) P=0.45
	Hybrid	5,091		1.11 (0.64-1.92) P=0.71
	Patellofemoral	5,867		0.67 (0.25-1.79) P=0.42
	Unicondylar	37,299		0.31 (0.19-0.51) P<0.001
Season	**Spring**	125,035		1 [referent]

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	Summer	128,458		0.75 (0.63-0.89) P=0.001
	Autumn	140,699		0.82 (0.69-0.95) P=0.014
	Winter	116,184		0.88 (0.75-1.05) P=0.16

**Excludes a small number of cases (4 hips and 7 knees) where gender was uncertain*

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Figure Legend

Figure 1. Cumulative 30-day mortality for patients undergoing primary A) hip or B) knee replacement in English and Welsh hospitals (Figures show Kaplan-Meier estimates with point-wise 95%CIs; overall comparison between weekday and weekend cases P=0.011 for hips and P=0.017 for knees, by logrank tests).

Figure 2. Cumulative 30-day mortality for patients undergoing primary A) hip or B) knee replacement stratified by type of hospital (Comparisons between weekday vs weekend cases for NHS hospitals, Independent Treatment Centres and Independent Hospitals respectively were P=0.010, P=0.32 and P=0.84 for hips and P=0.002, P=0.97 and P=0.12 for knees, by logrank tests).

Figure 3. Effect of operating surgeon seniority on cumulative 30-day mortality in NHS hospitals after primary A) hip or B) knee replacement (Figures show Kaplan-Meier estimates with point-wise 95%CIs; comparisons between consultant and 'other' P=0.87 for hips and P=0.95 for knees, by logrank tests).

Figure 4. Effect of season on cumulative 30-day mortality in NHS hospitals after primary A) hip or B) knee replacement (Figures show Kaplan-Meier estimates but point-wise 95%CIs omitted for simplicity; comparisons between the four seasons P=0.69 for hips and P=0.017 for knees, by logrank tests).

Figure 5. Cumulative 30-day mortality for primary A) hip or B) knee operations performed at weekend (red) versus weekday (blue) in NHS hospitals over the 4 time periods studied (Comparisons between weekday vs weekend cases for 2003-5, 2006-8, 2009-11 and 2012-14, respectively, were P=0.38, P=0.39, P=0.070 and P=0.014 for hips and P=0.84, P=0.24, P=0.007 and P=0.056 for knees, by logrank tests).

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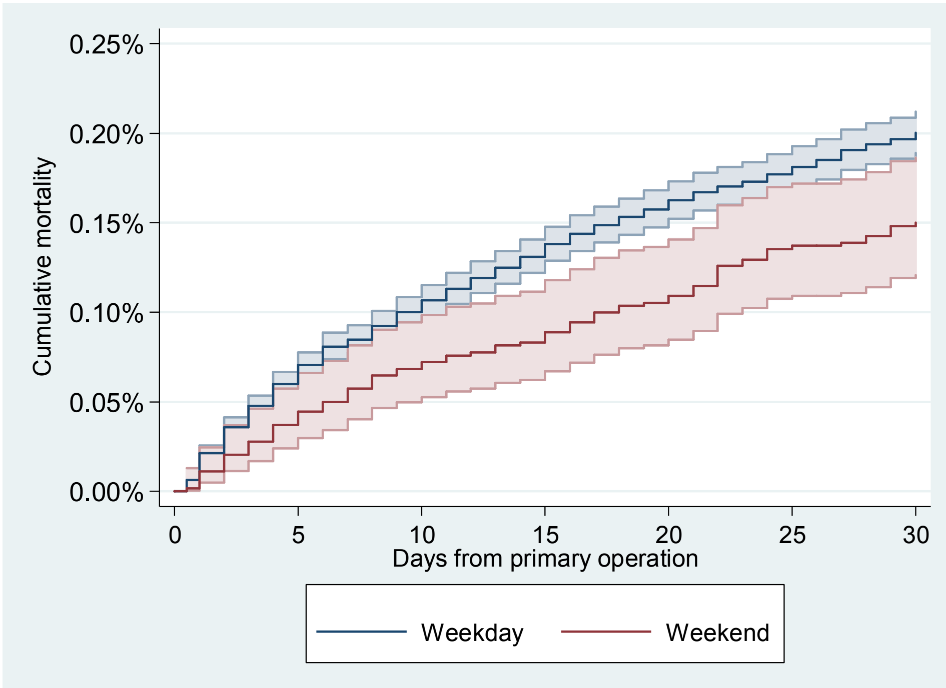
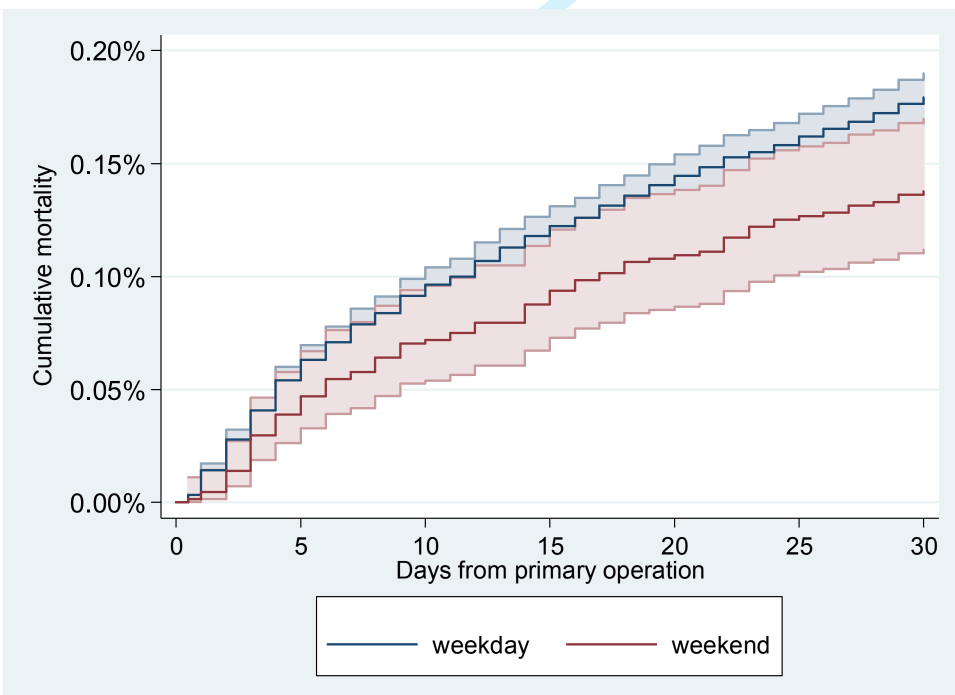
A


0.25%
0.20%
0.15%
0.10%
0.05%
0.00%
Cumulative mortality
0
5
10
15
20
25
30
Days from primary operation
Weekday
Weekend

B


0.20%
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Cumulative mortality
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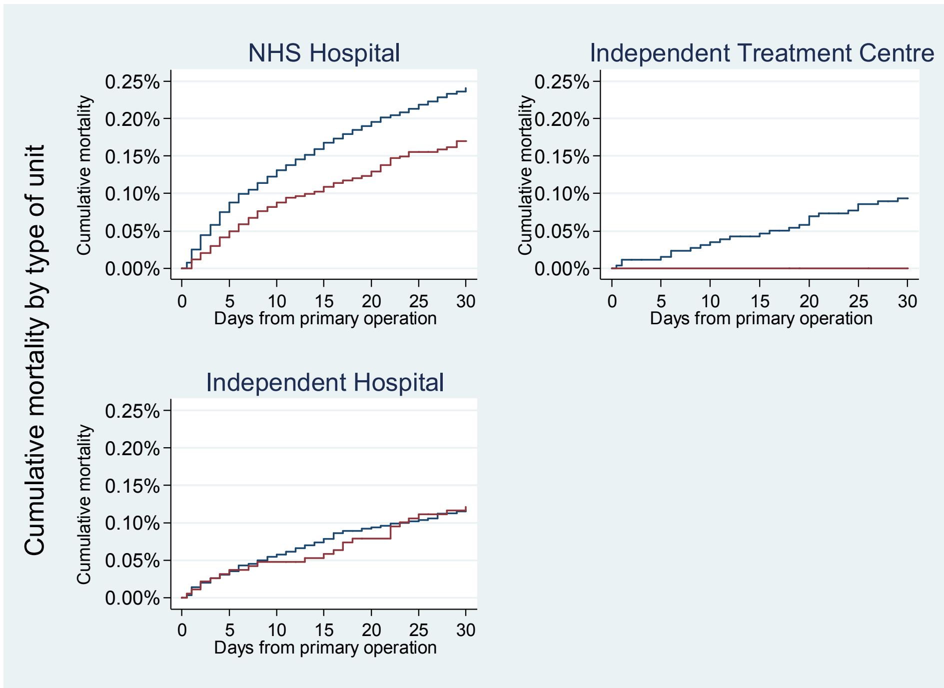
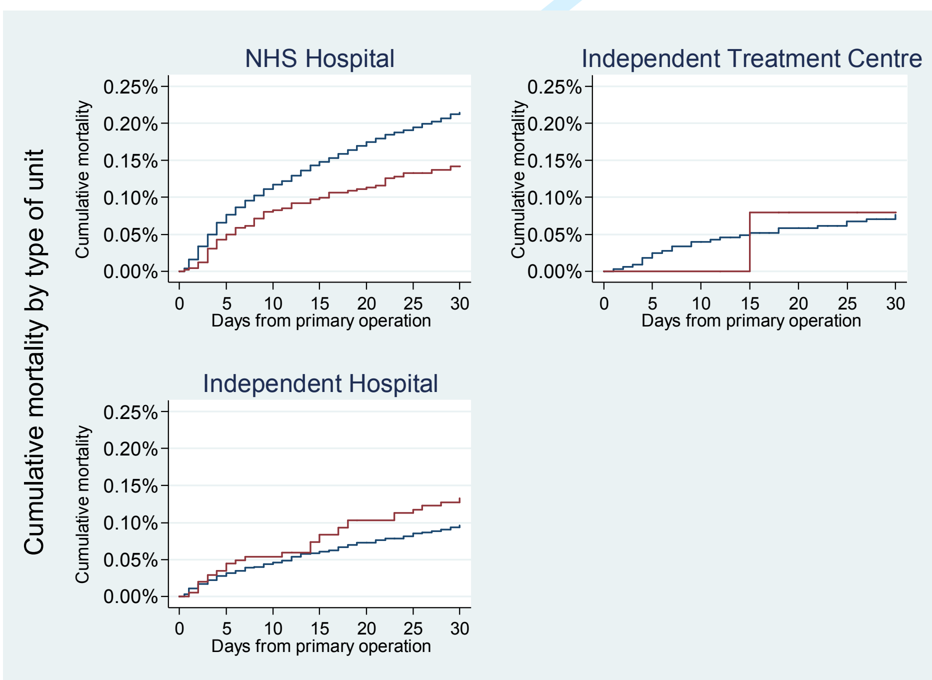
15
20
25
30
Days from primary operation
weekday
weekend

A



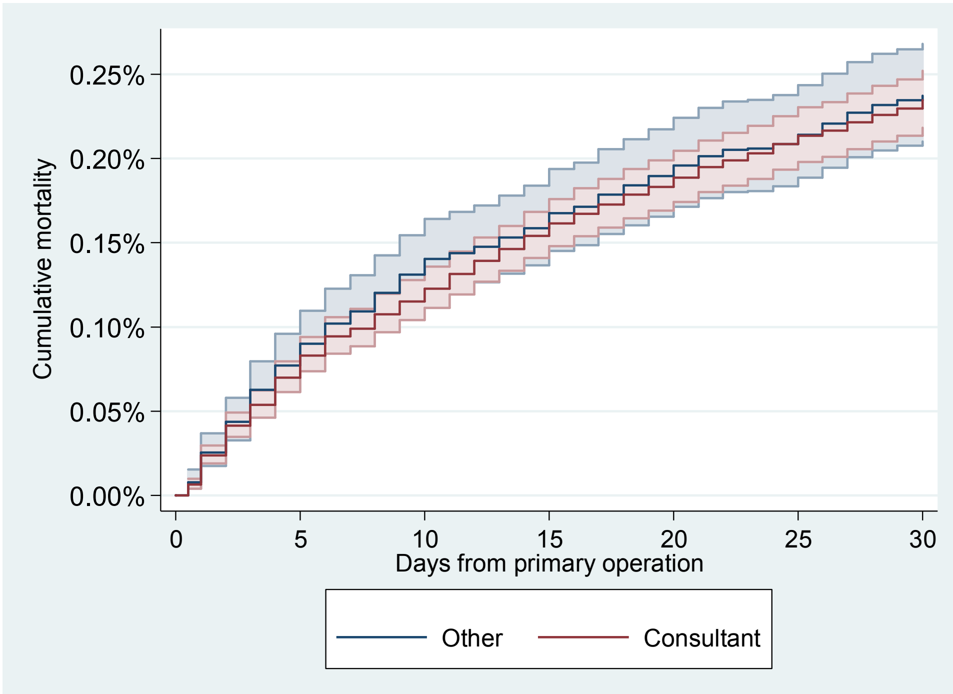
Cumulative mortality by type of unit
NHS Hospital
Independent Treatment Centre
Independent Hospital
Cumulative mortality
0.25%
0.20%
0.15%
0.10%
0.05%
0.00%
0
5
10
15
20
25
30
Days from primary operation

B



Cumulative mortality by type of unit
NHS Hospital
Independent Treatment Centre
Independent Hospital
Cumulative mortality
0.25%
0.20%
0.15%
0.10%
0.05%
0.00%
0
5
10
15
20
25
30
Days from primary operation

A


Cumulative mortality
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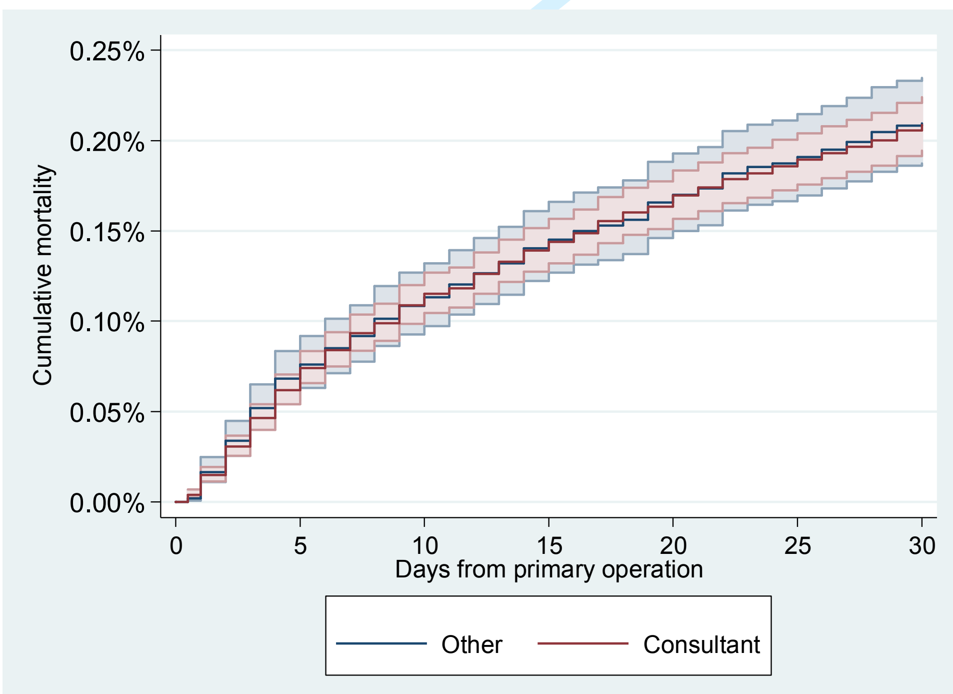
0.05%
0.10%
0.15%
0.20%
0.25%
0
5
10
15
20
25
30
Days from primary operation
Other
Consultant

B


Cumulative mortality
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0.05%
0.10%
0.15%
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0.25%
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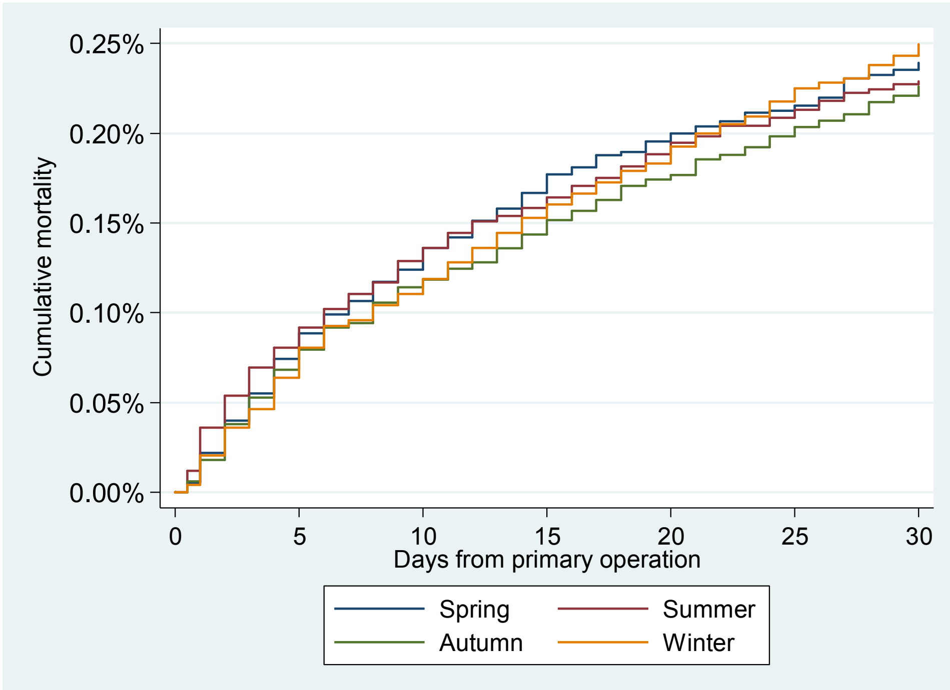
20
25
30
Days from primary operation
Other
Consultant

A


0.25%
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Cumulative mortality
0
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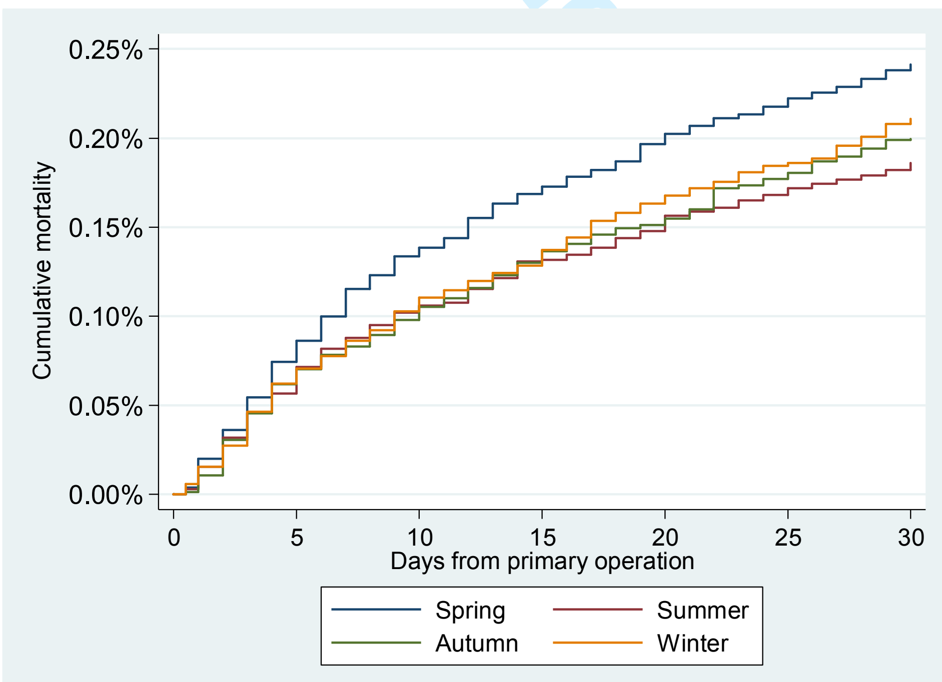
Days from primary operation
Spring
Summer
Autumn
Winter

B


0.25%
0.20%
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Cumulative mortality
0
5
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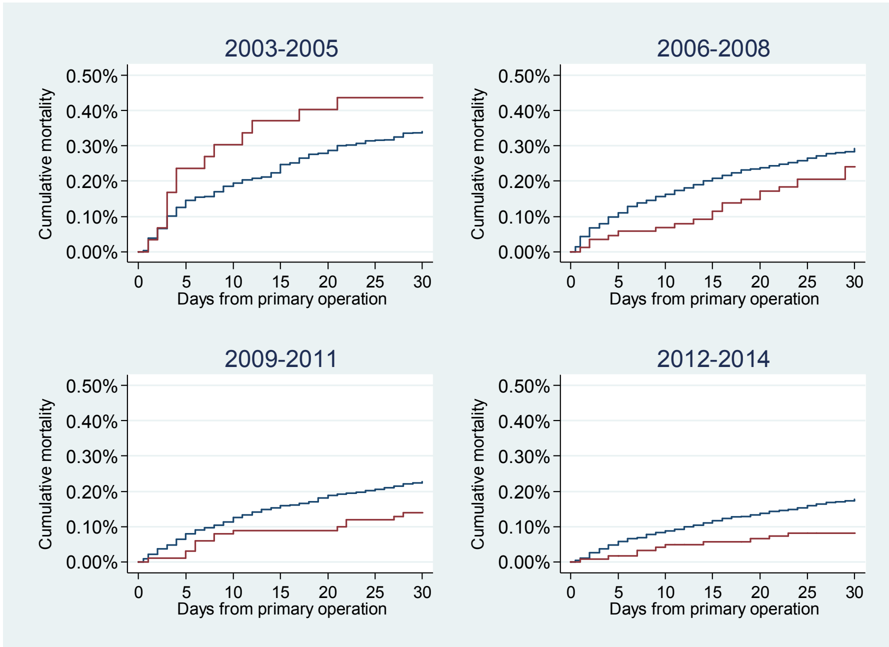
25
30
Days from primary operation
Spring
Summer
Autumn
Winter

A


2003-2005
2006-2008
2009-2011
2012-2014
Cumulative mortality
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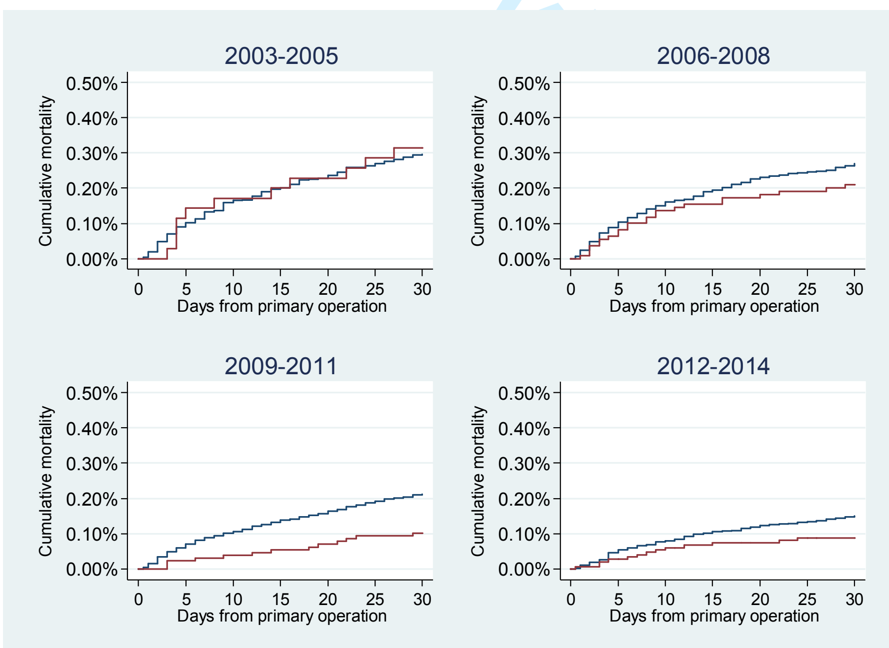
0.10%
0.20%
0.30%
0.40%
0.50%
0 5 10 15 20 25 30
Days from primary operation

B


2003-2005
2006-2008
2009-2011
2012-2014
Cumulative mortality
0.00%
0.10%
0.20%
0.30%
0.40%
0.50%
0 5 10 15 20 25 30
Days from primary operation